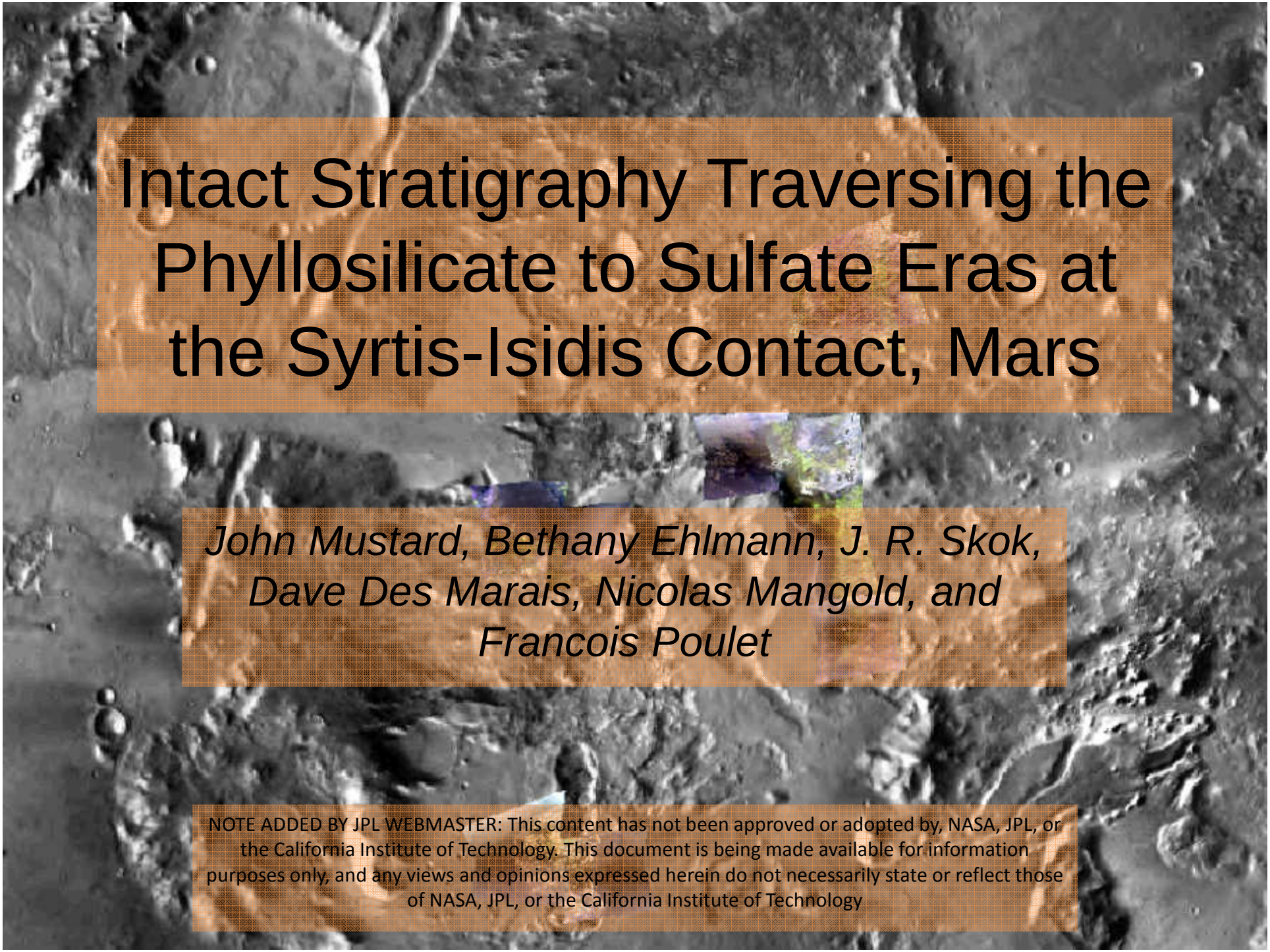
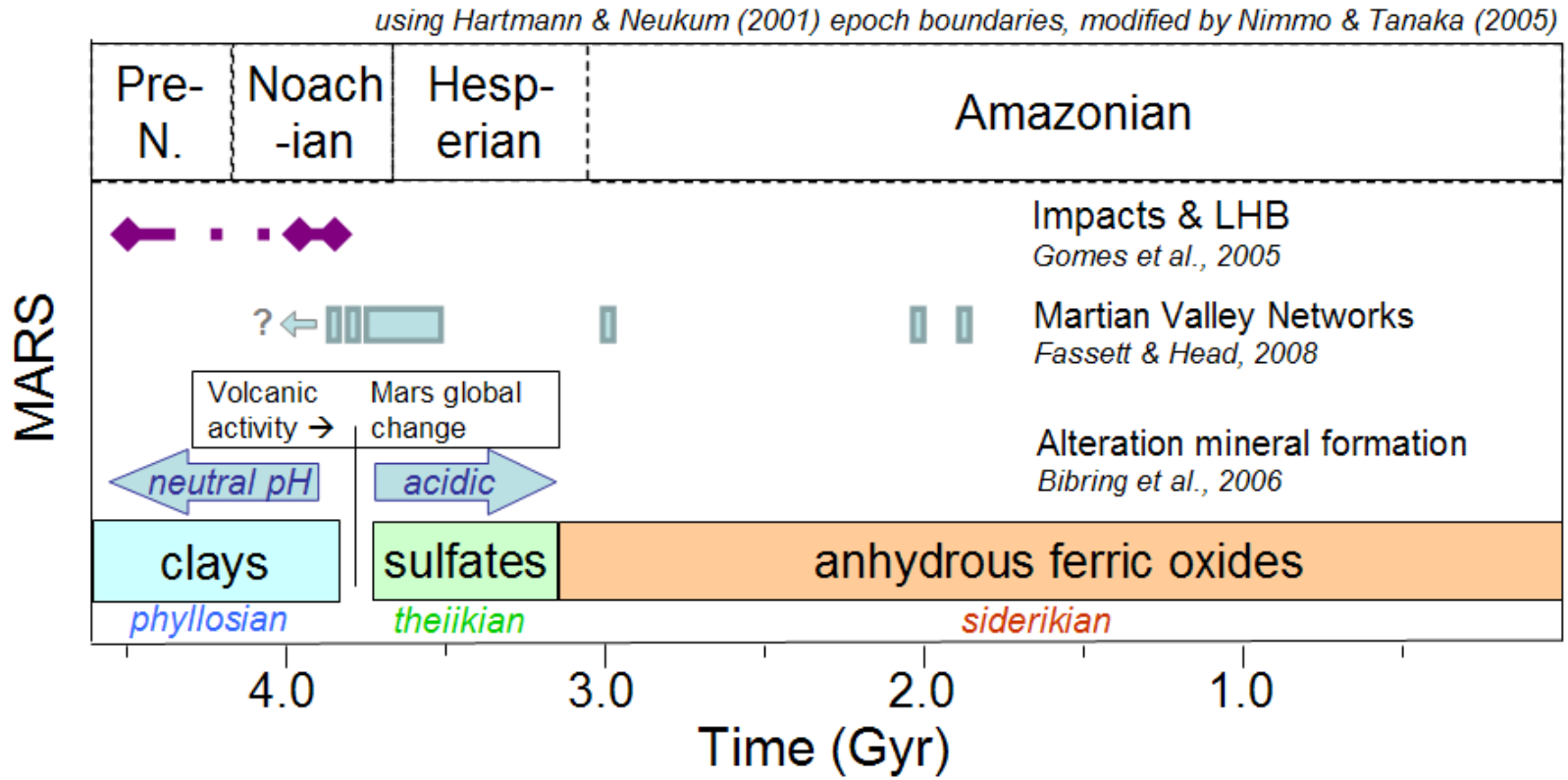
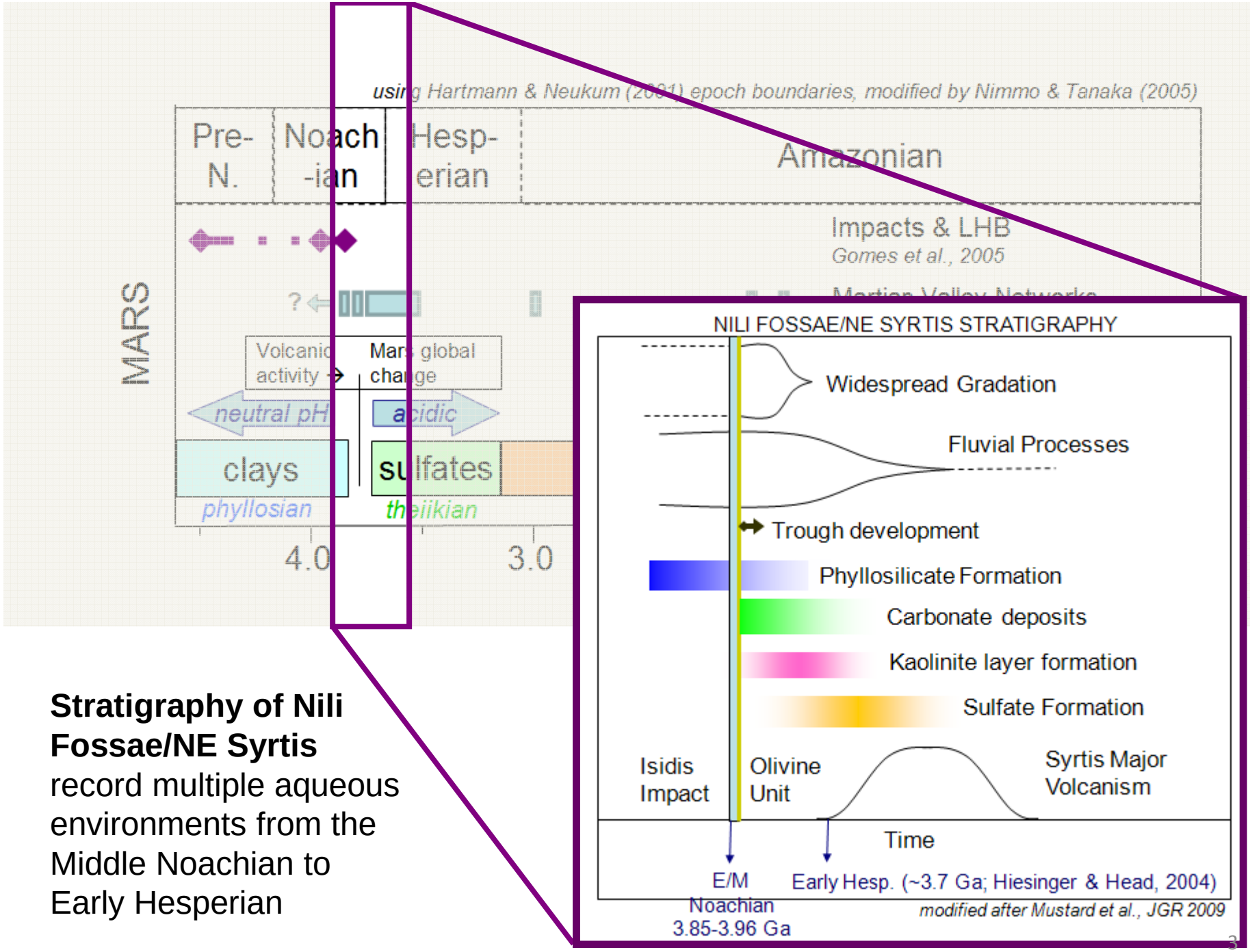


Intact Stratigraphy Traversing the Phyllosilicate to Sulfate Eras at the Syrtis-Isidis Contact, Mars

John Mustard, Bethany Ehlmann, J. R. Skok, Dave Des Marais, Nicolas Mangold, and Francois Poulet



Stratigraphy of Nili Fossae/NE Syrtis record multiple aqueous environments from the Middle Noachian to Early Hesperian



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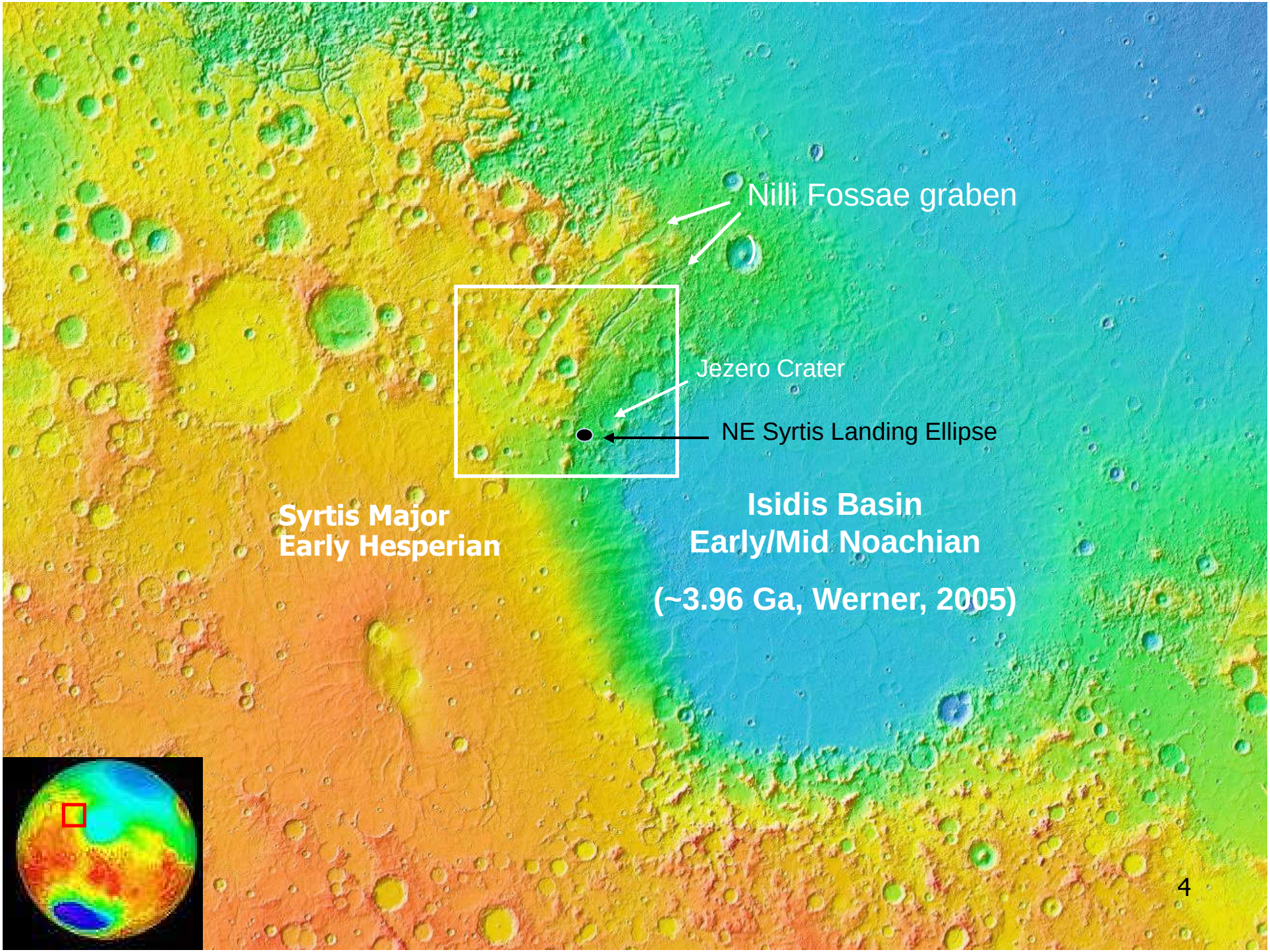
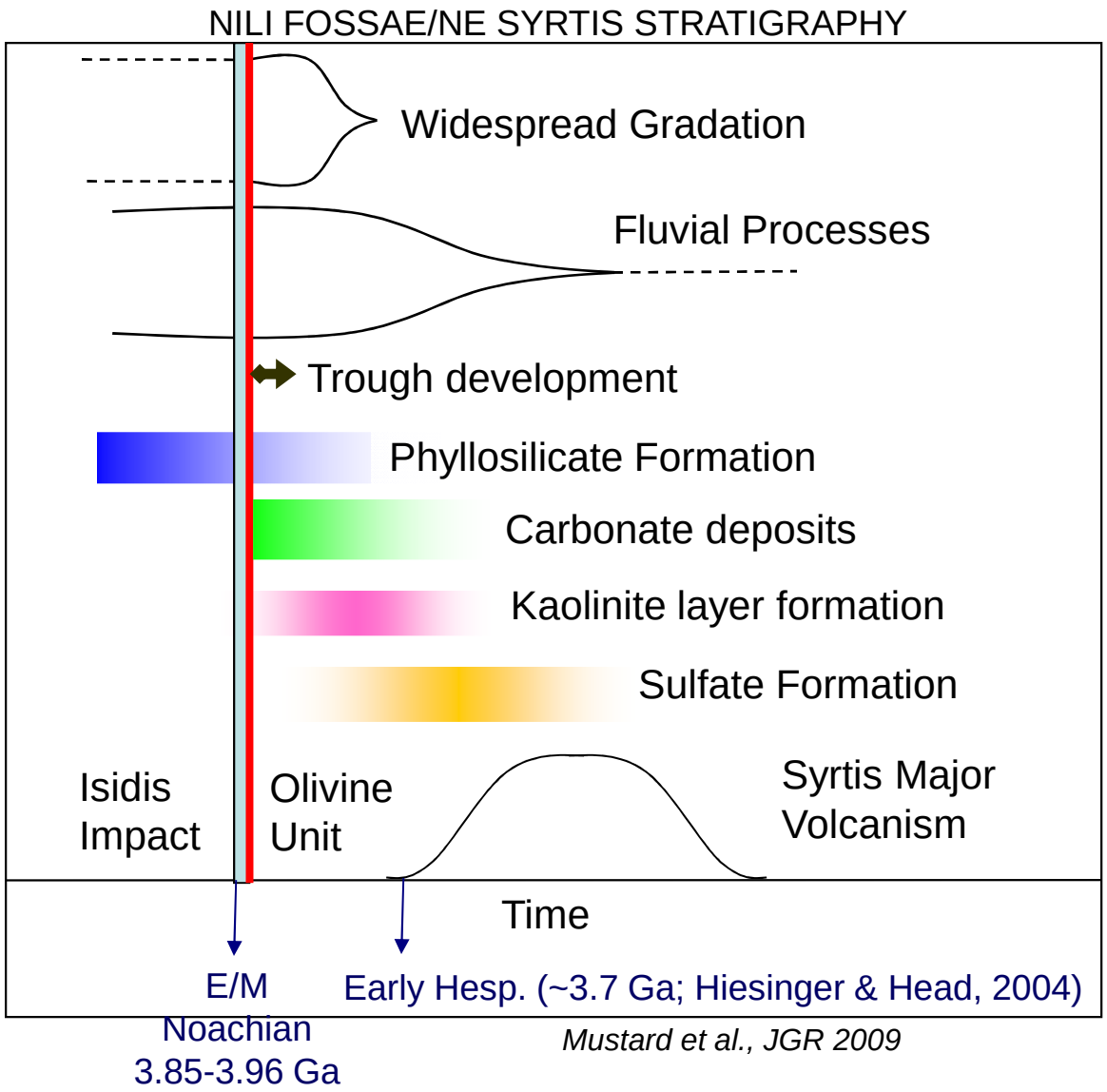

Nilli Fossae graben
Jezero Crater
NE Syrtis Landing Ellipse
Syrtis Major
Early Hesperian
Isidis Basin
Early/Mid Noachian
(~3.96 Ga, Werner, 2005)

Chronology of Geological Processes Defined in a Mineralogic/Morphologic Stratigraphy Across 1000s km^2



Isidis Basin and Syrtis Major lavas are major time-stratigraphic markers

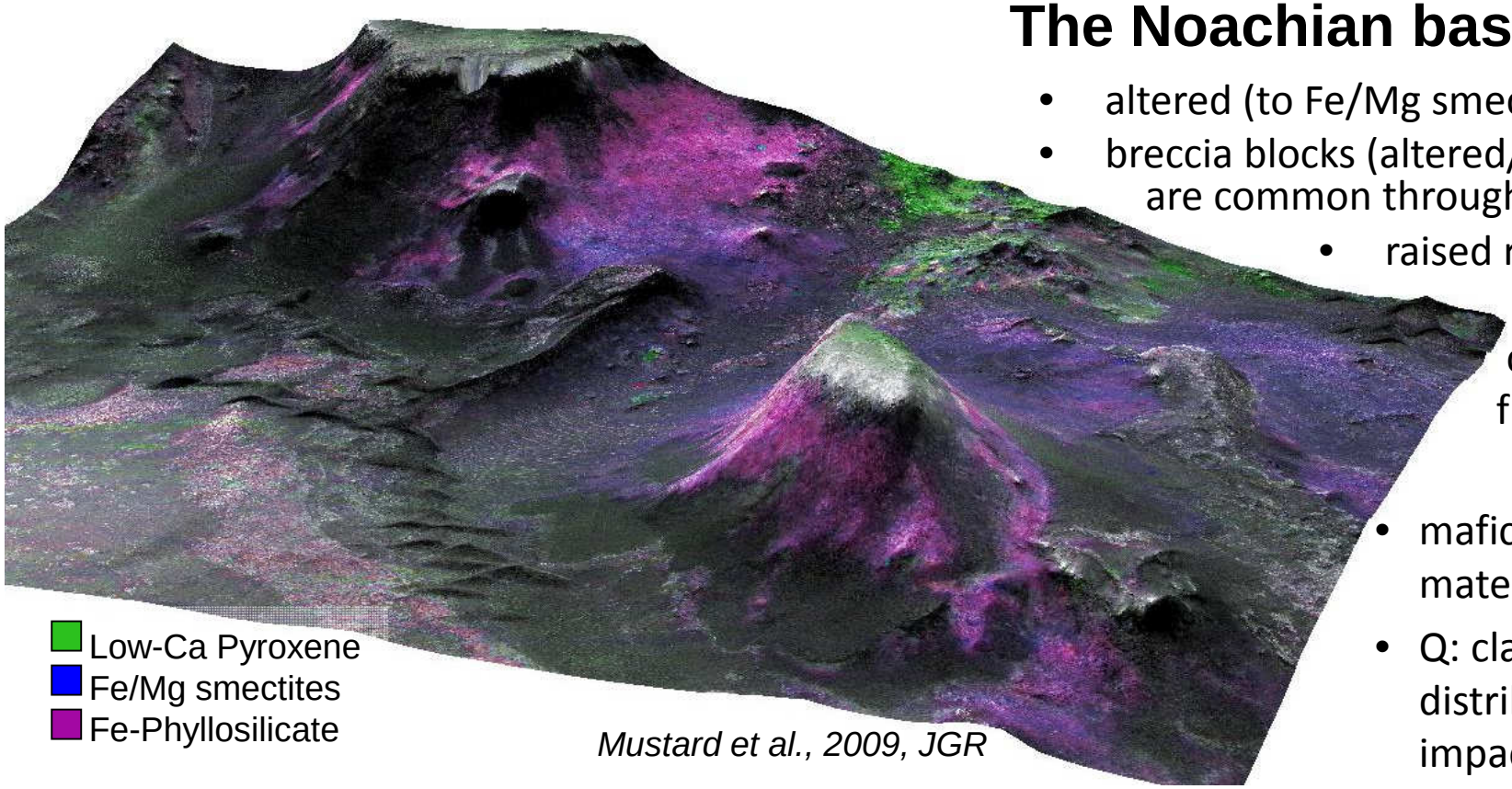
Significant gradation (mass wasting? aeolian? alluvial? all?) between Isidis basin formation and Syrtis lava emplacement

Defined wet periods, marked by mineralogy & morphology

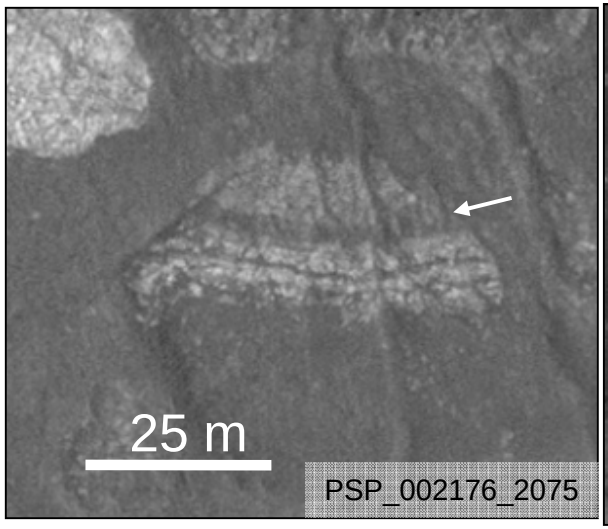
The Noachian basement

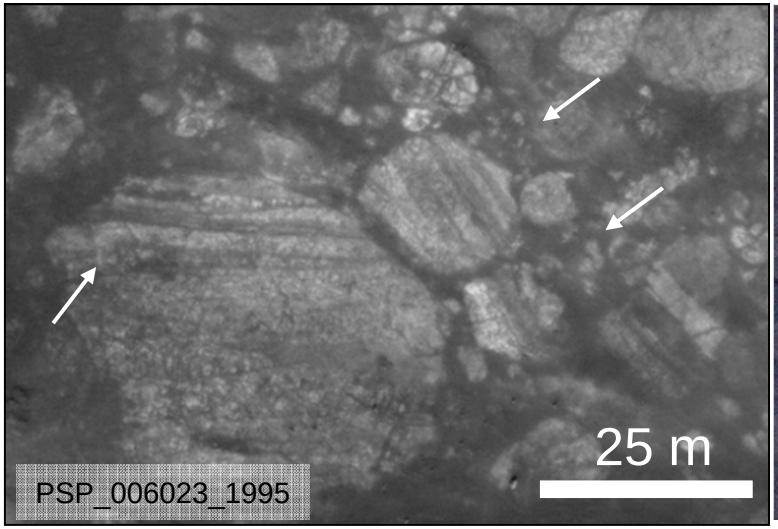
- altered (to Fe/Mg smectite)
- breccia blocks (altered/unaltered) are common throughout
- raised ridges upon erosion: conduits of fluid flow?

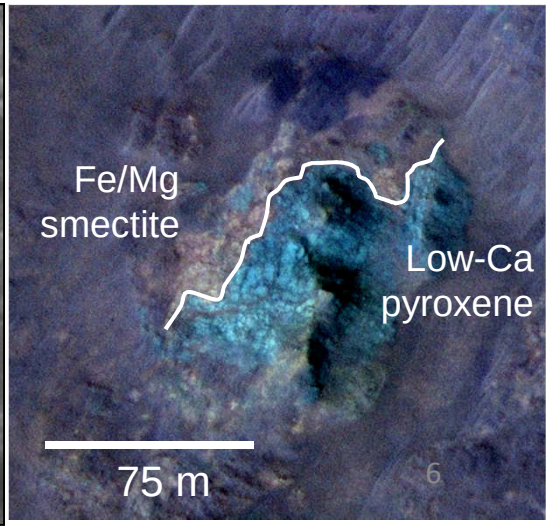
- mafic (low-Ca pyx) materials cap
- Q: clays created or distributed by impact



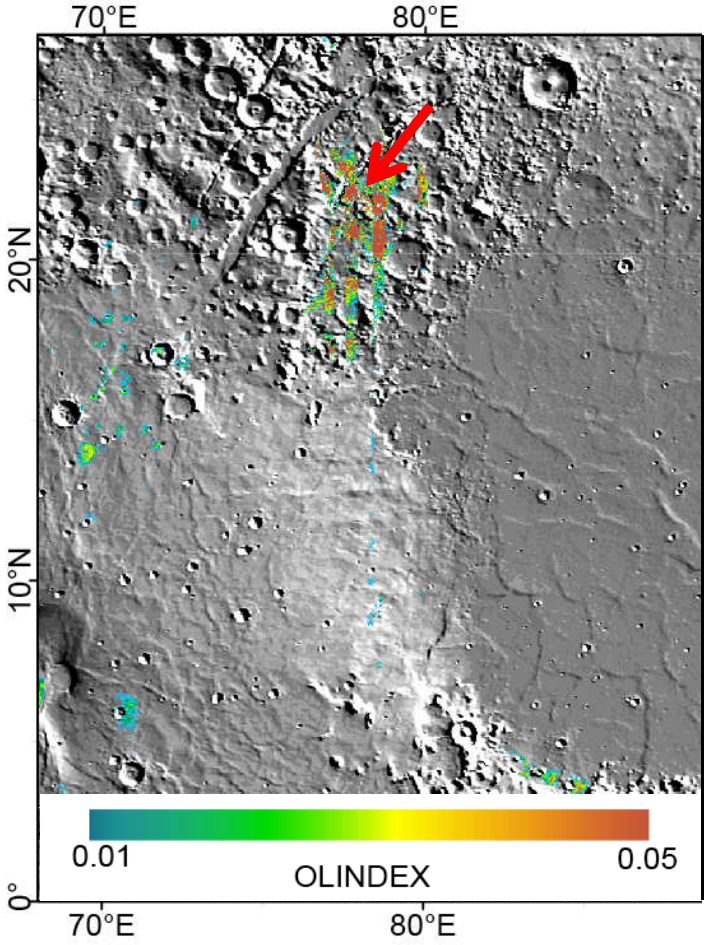
Mustard et al., 2009, JGR



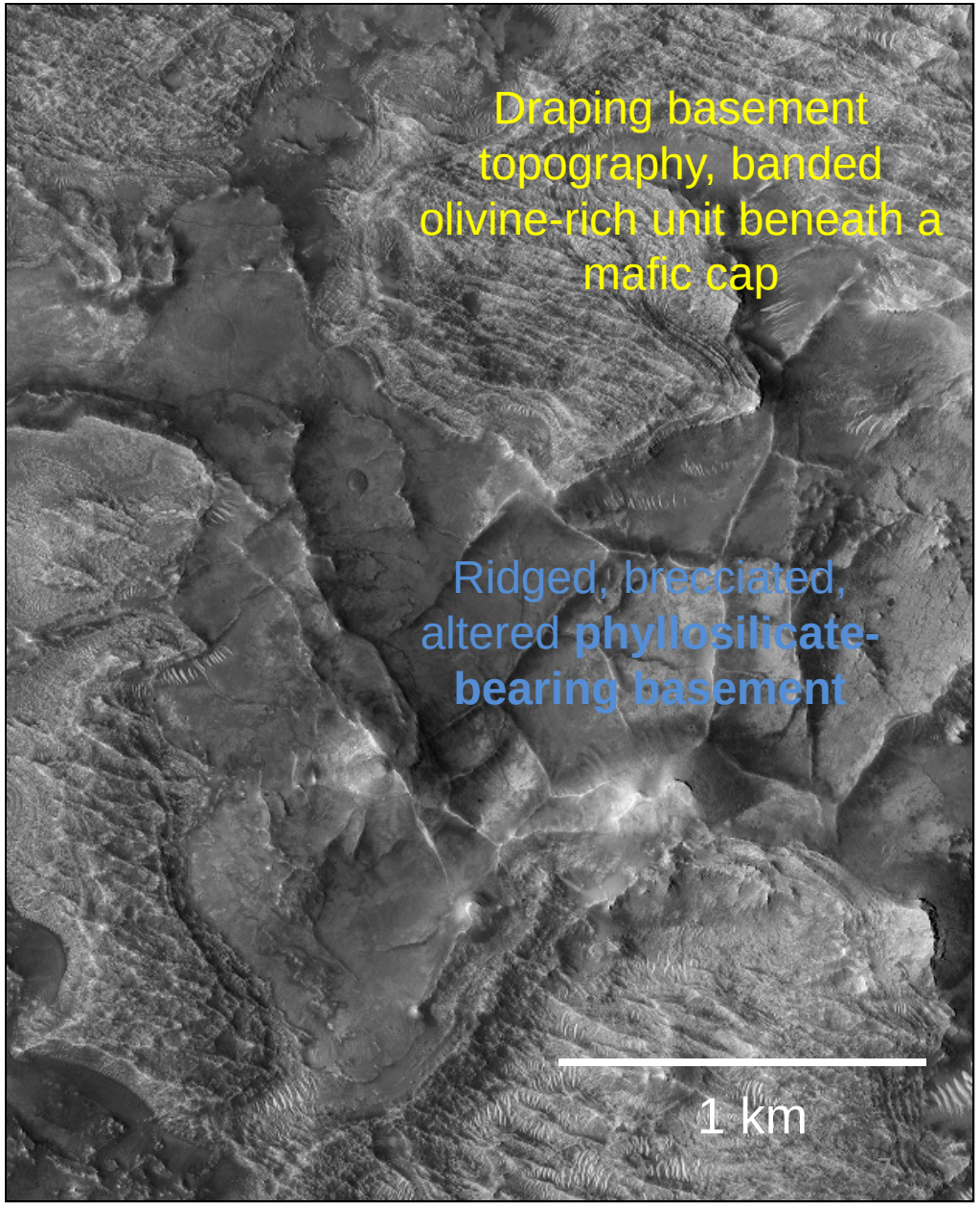


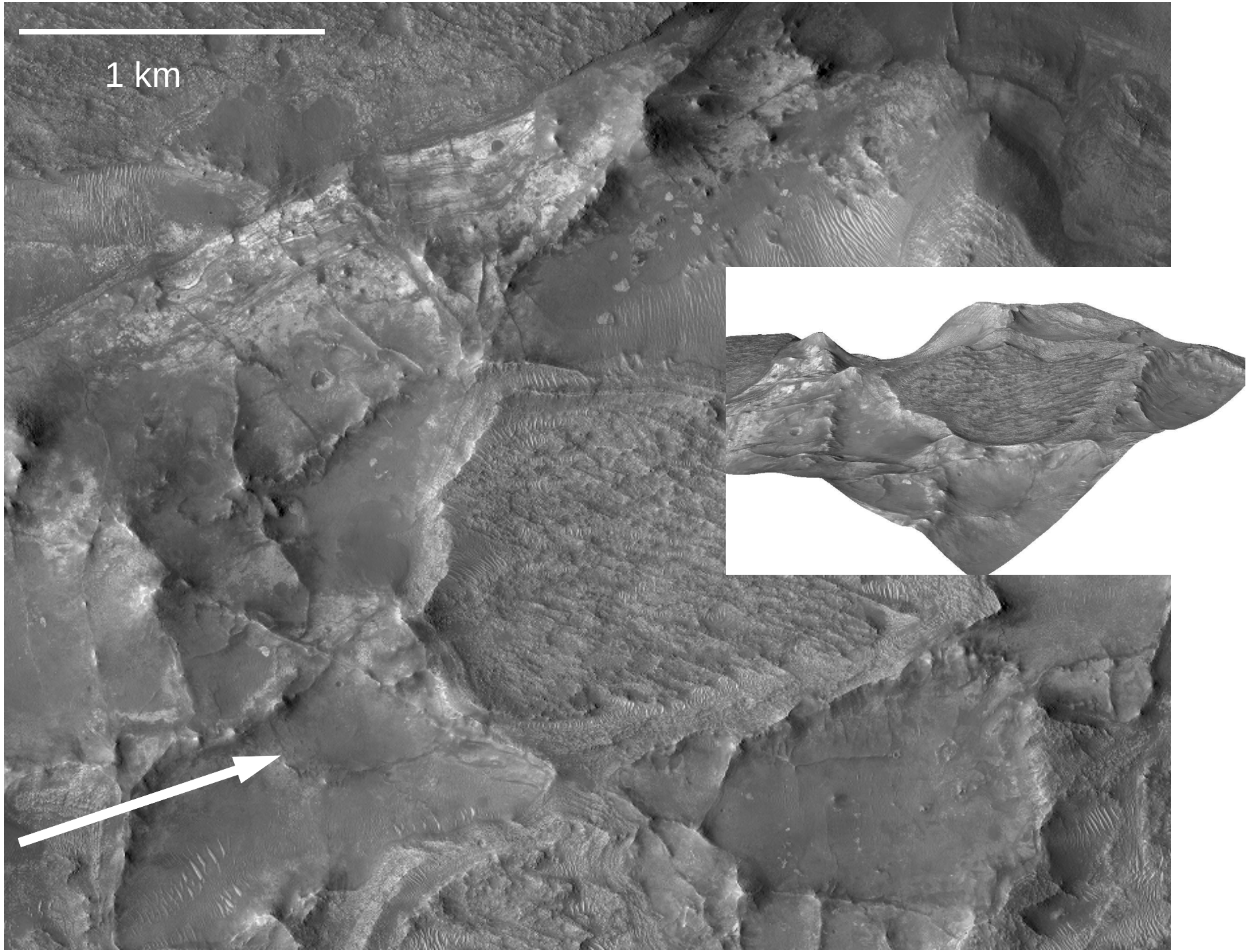


Widespread olivine-bearing unit is a distinctive stratigraphic marker
Shows the same texture, thickness, and composition across 1000s km^2



- Volcanic flows [Tornabene et al. 2007] vs impact melt [Mustard etal., 2007]
- Drapes topography and is cut by fossae
- Associated with carbonate and serpentine in the region near and north of Jezero Crater

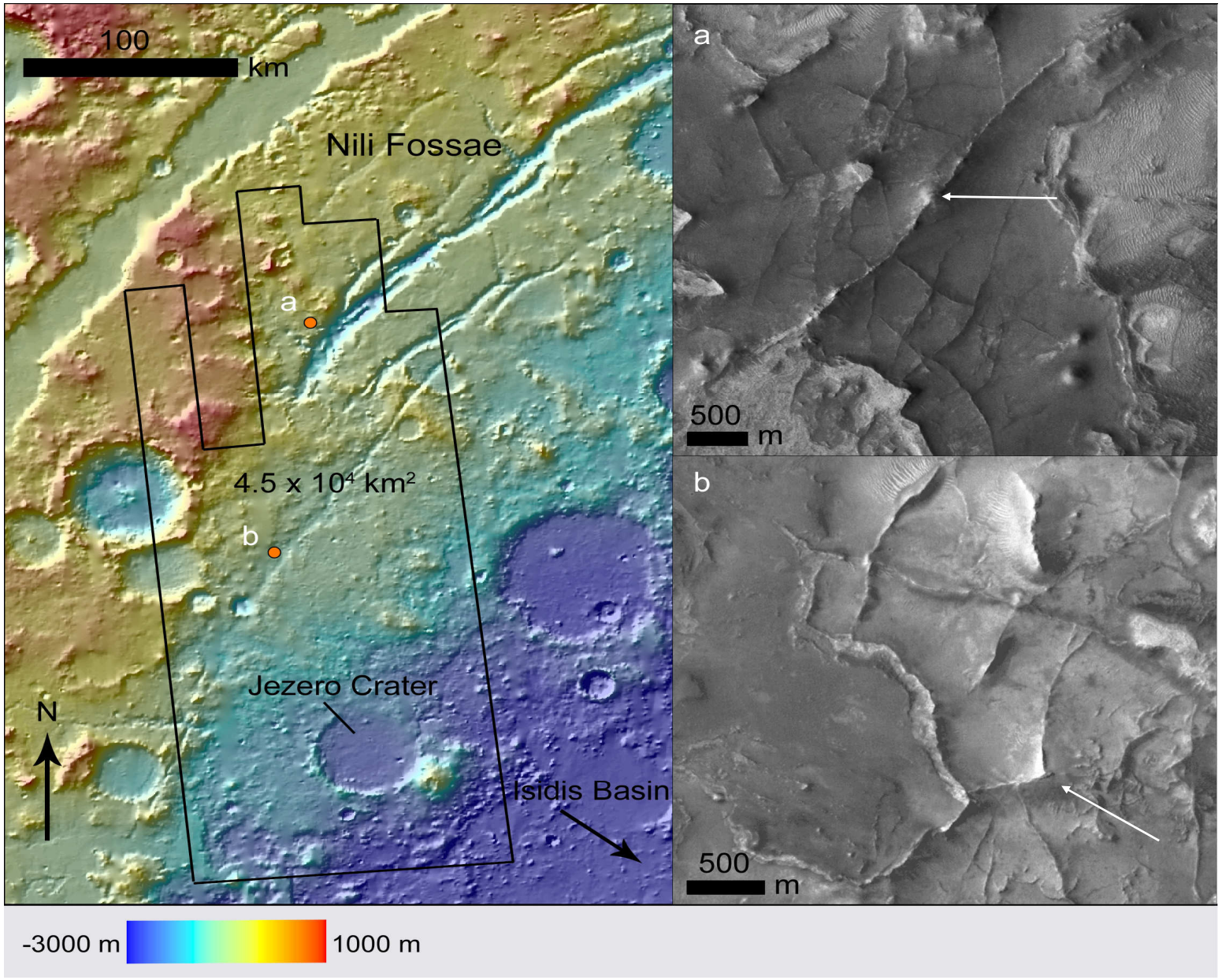



1 km

Morphology and Orientation of Ridges

Widespread ridges in the Noachian crustal unit, 10s m wide, 100s m long

Mapping of over 2200 ridges shows a NE-SW orientation that parallels Nili Fossae



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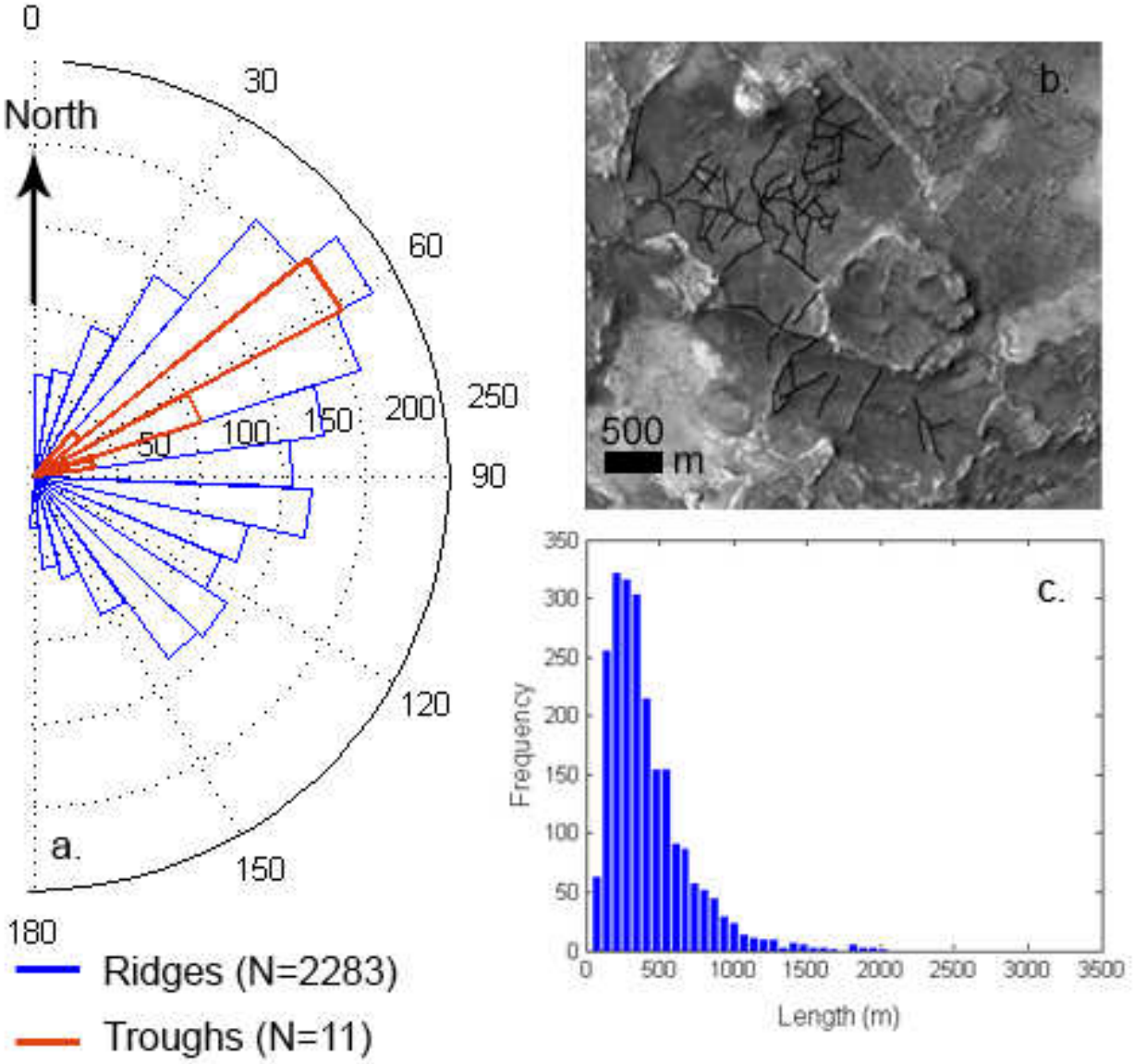
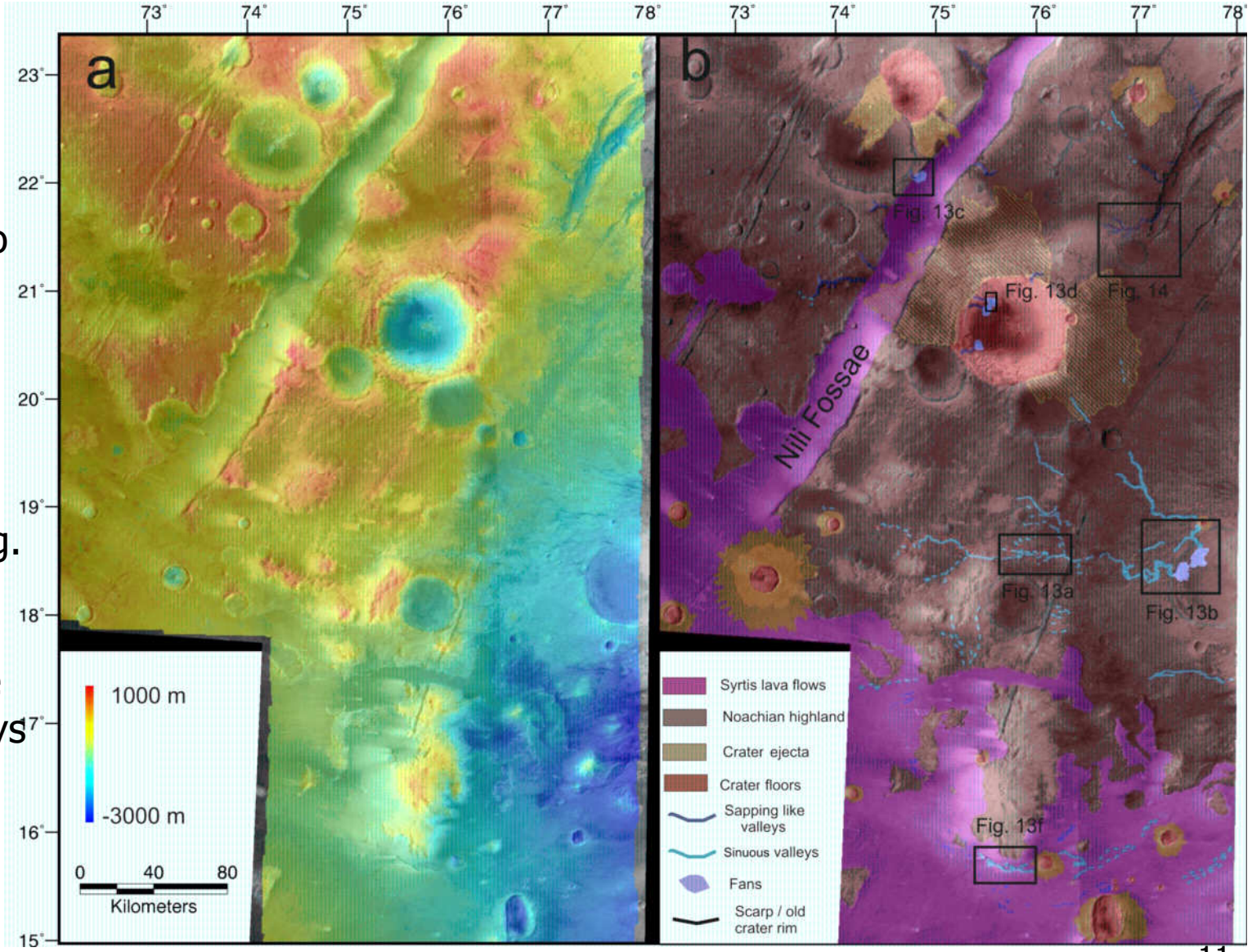


Fluvial Channels in Nili Fossae

Active from Noachian into Hesperian

Both well-developed drainage networks (e.g. Jezero) and short, amphitheatre headed valleys



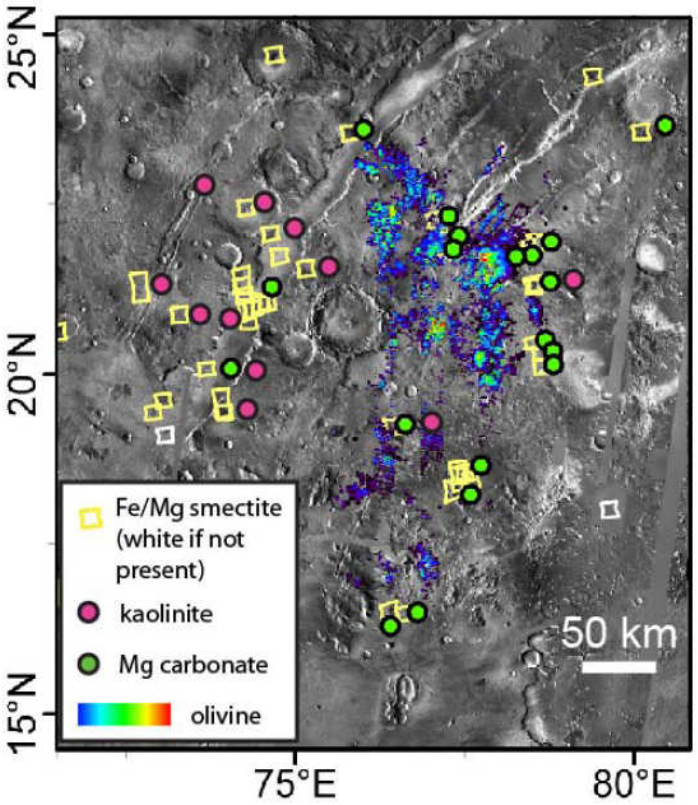
Mangold et al., *JGR*, 2007

Kaolinite-smectite alteration

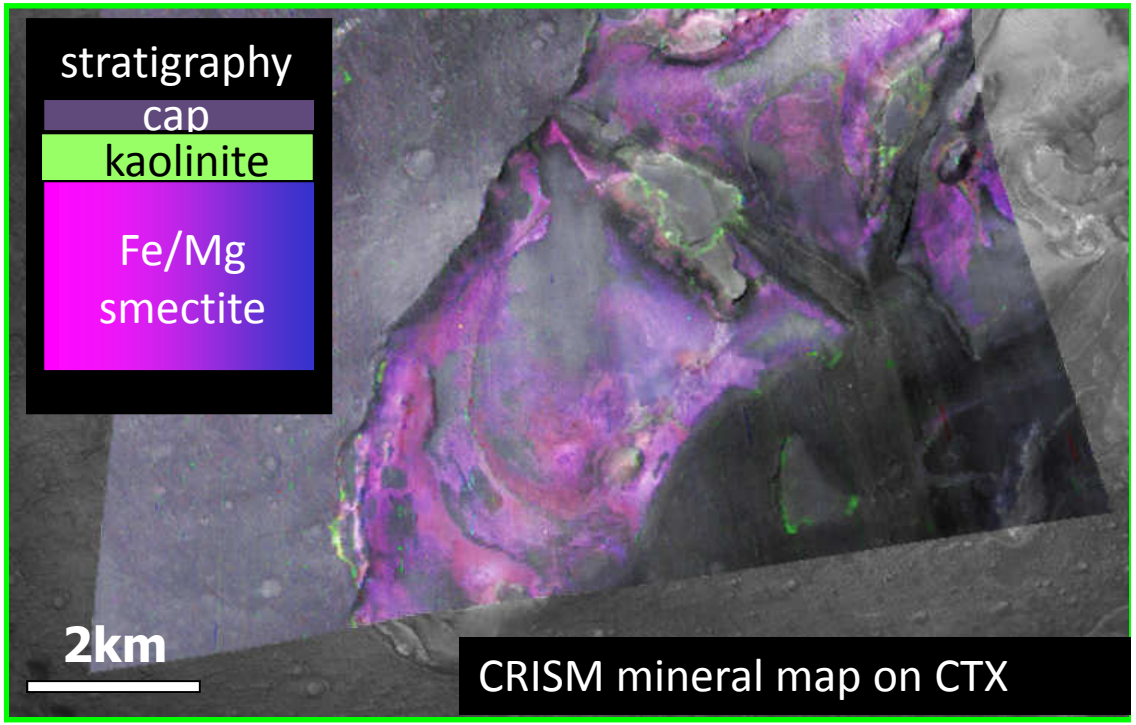
occurs where precursor rock is not olivine-rich (pyx, Fe/Mg smectite)

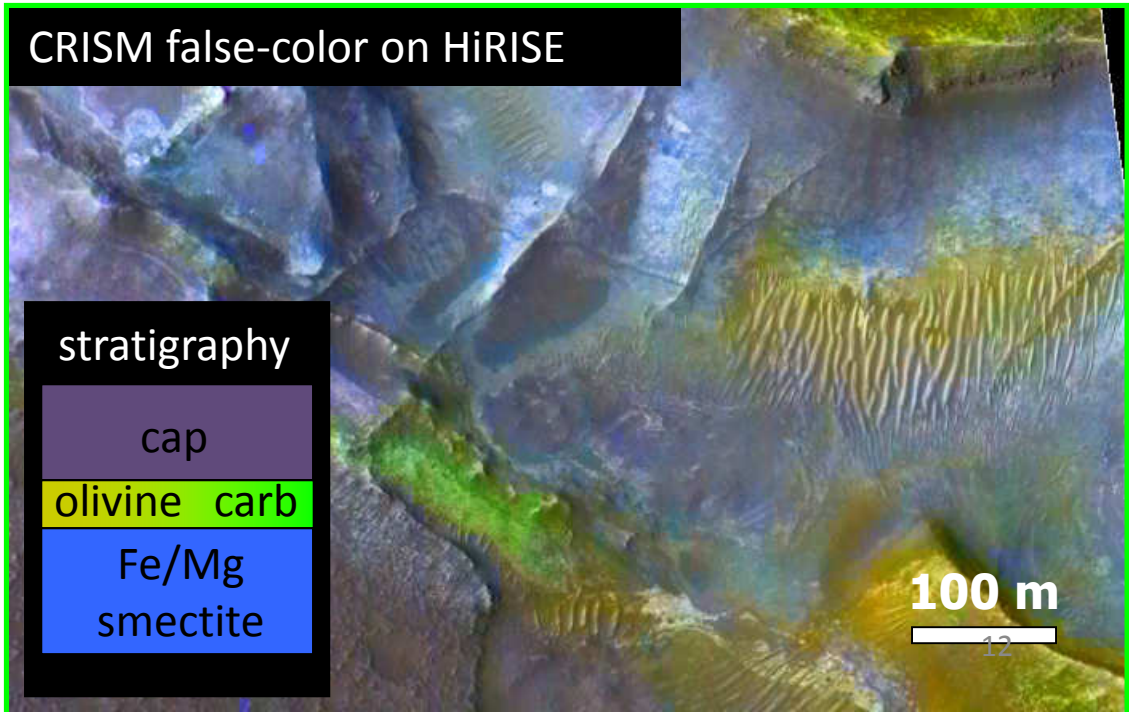
Carbonate-smectite alteration

occurs where precursor rock is olivine-rich



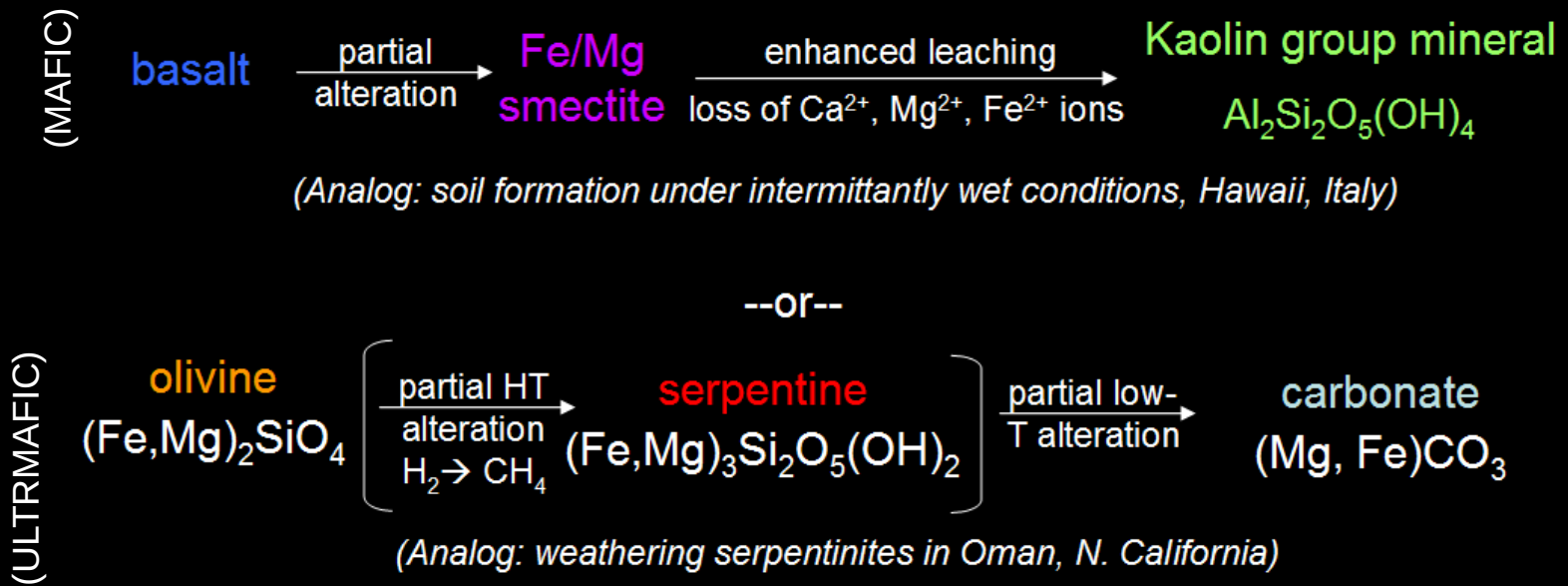
Ehlmann et al., Science 2008;
Ehlmann et al., *JGR*, 2009





Kaolinite, carbonate, and serpentine mineralization

- Chemistry controlled by precursor mineralogy



- Carbonate: Surface alteration related to near-surface hydrology? Hydrothermal serpentinizing system?
  - H_2 an energy source for organisms, potential for methane production
- Kaolinite: Leaching from an active hydrologic system

NE SYRTIS: Ellipse and Go-To Science

Cross the Noachian-Hesperian boundary and the transition from phyllosilicate/carbonate (alkaline) to sulfate (acidic)

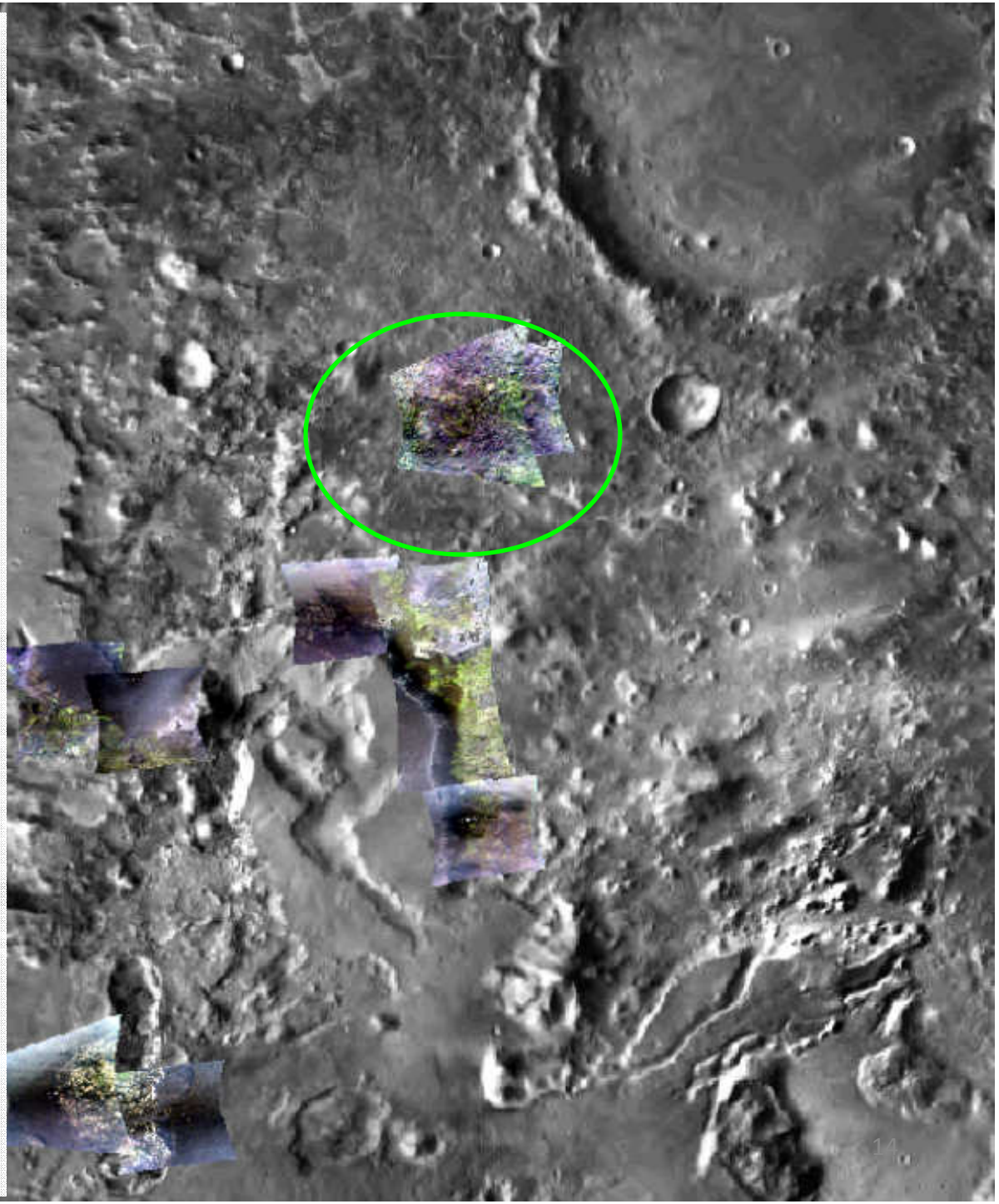
Investigate hydrothermal, fluvial, and volcano-ice interactions which present a number of diverse habitable environments on early Mars

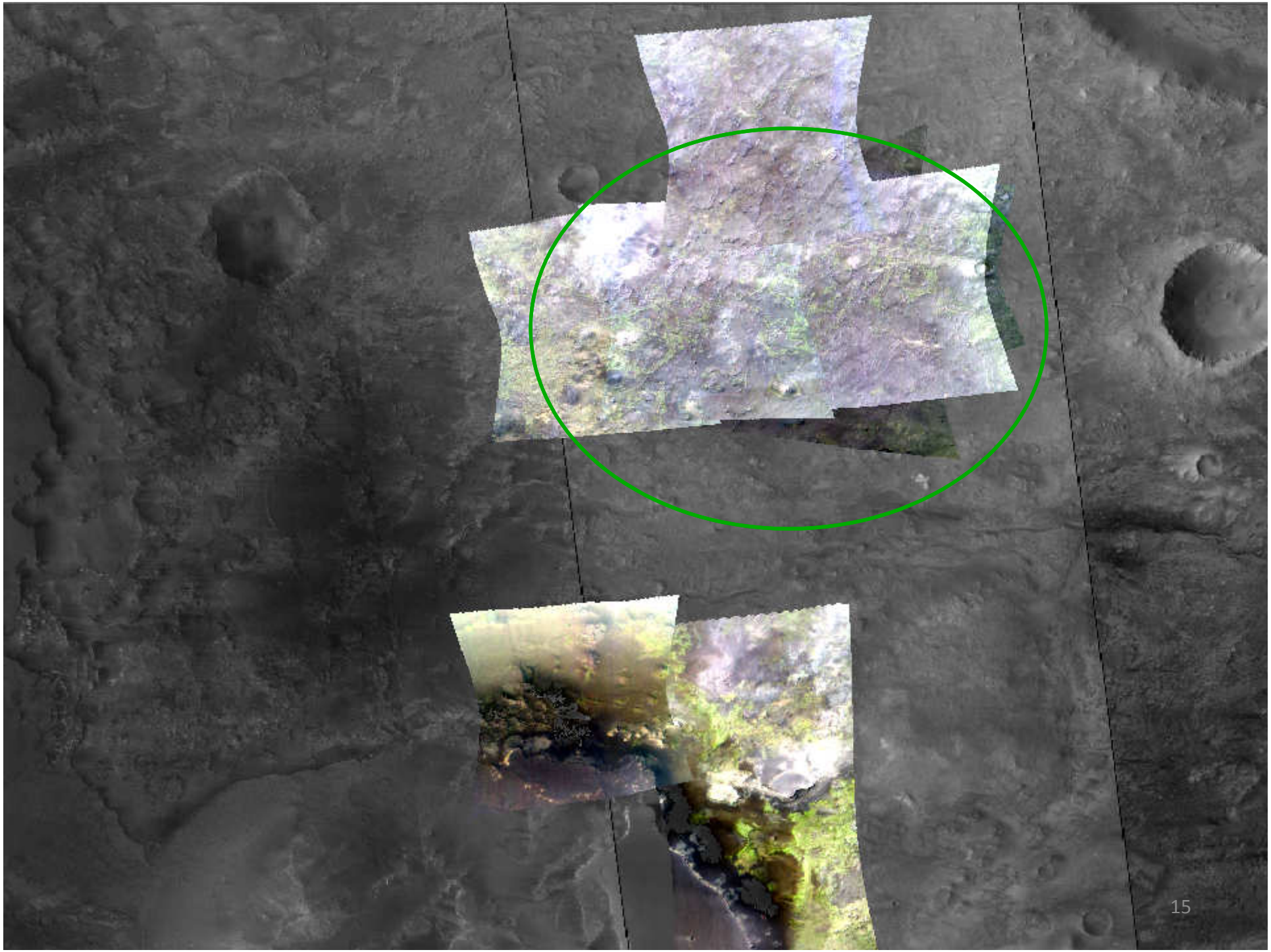
Thick sedimentary sequence is accessible at the go-to site

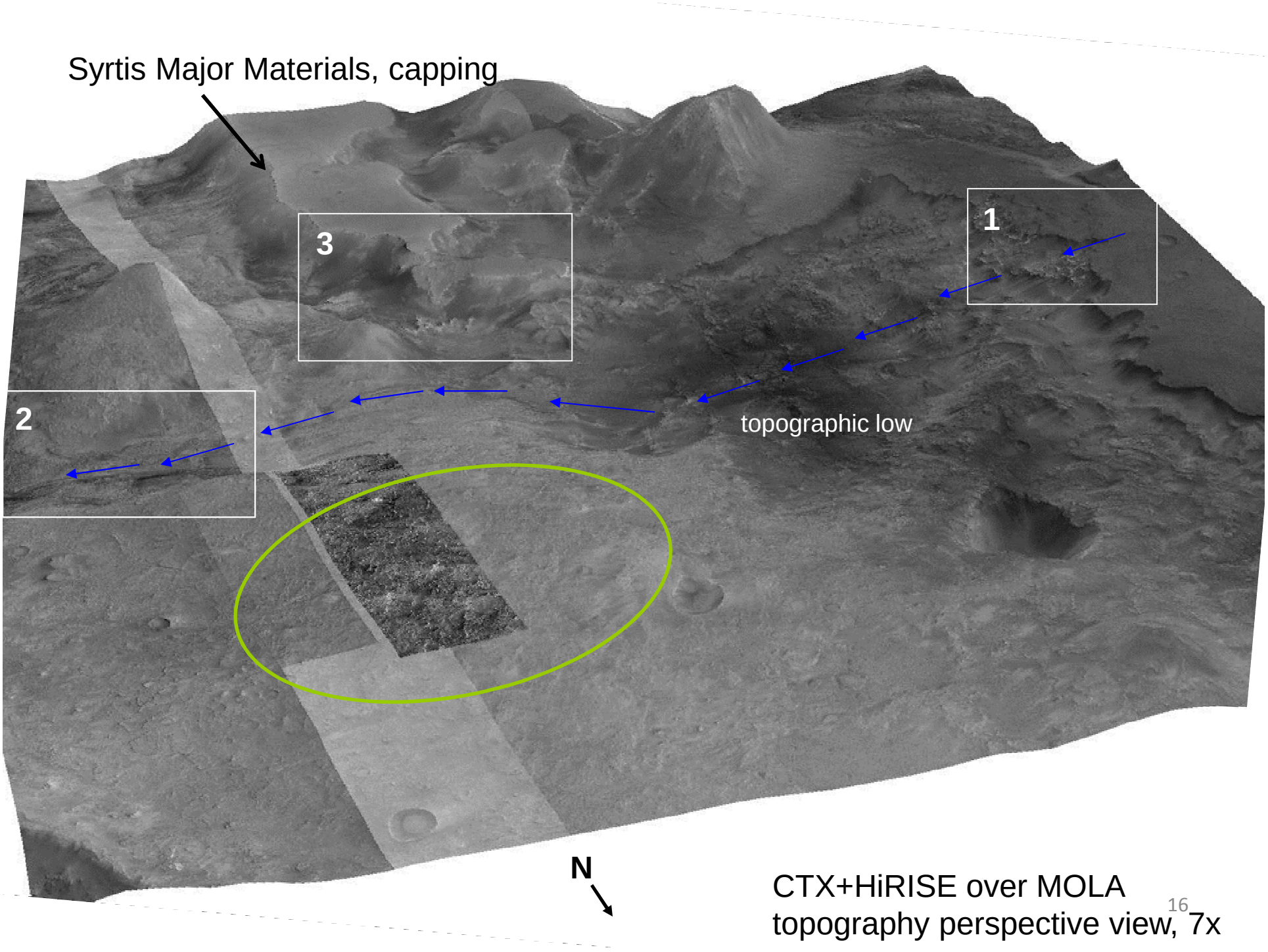
In-ellipse science includes immediate investigation of Noachian alteration in breccias and of kaolinite and carbonate alteration with reactants and products in direct association

Extended region includes four distinct aqueous environments with clear local stratigraphic relationships that fit within a regional stratigraphic and geologic framework

Fe/Mg smectite basement, kaolinite alteration, olivine-rich unit with serpentine and carbonate alteration, Hesperian volcanic flows emplaced on sediments and interacting with volatile-rich deposits with hydrothermal alteration and sulfate mineral deposition

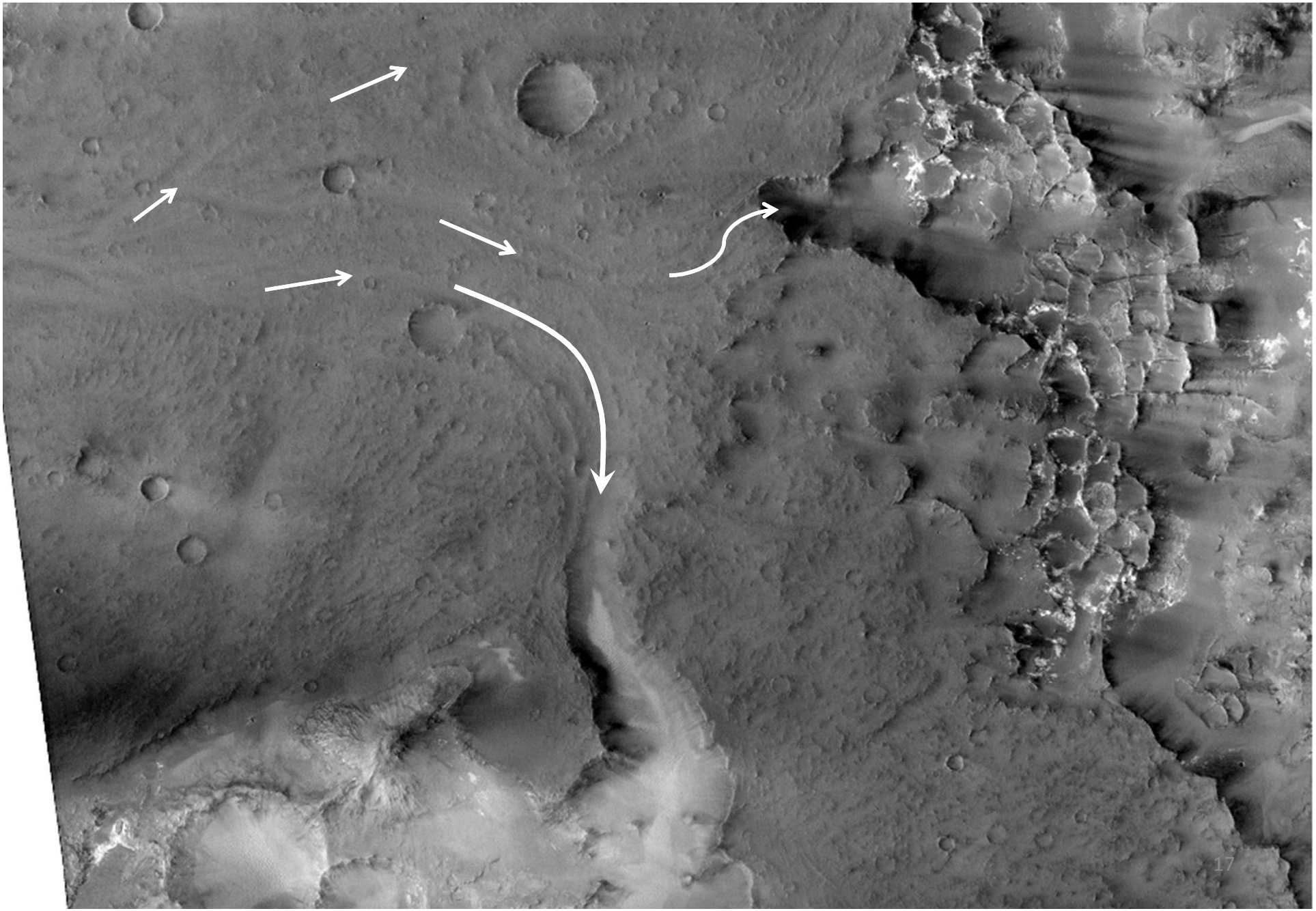




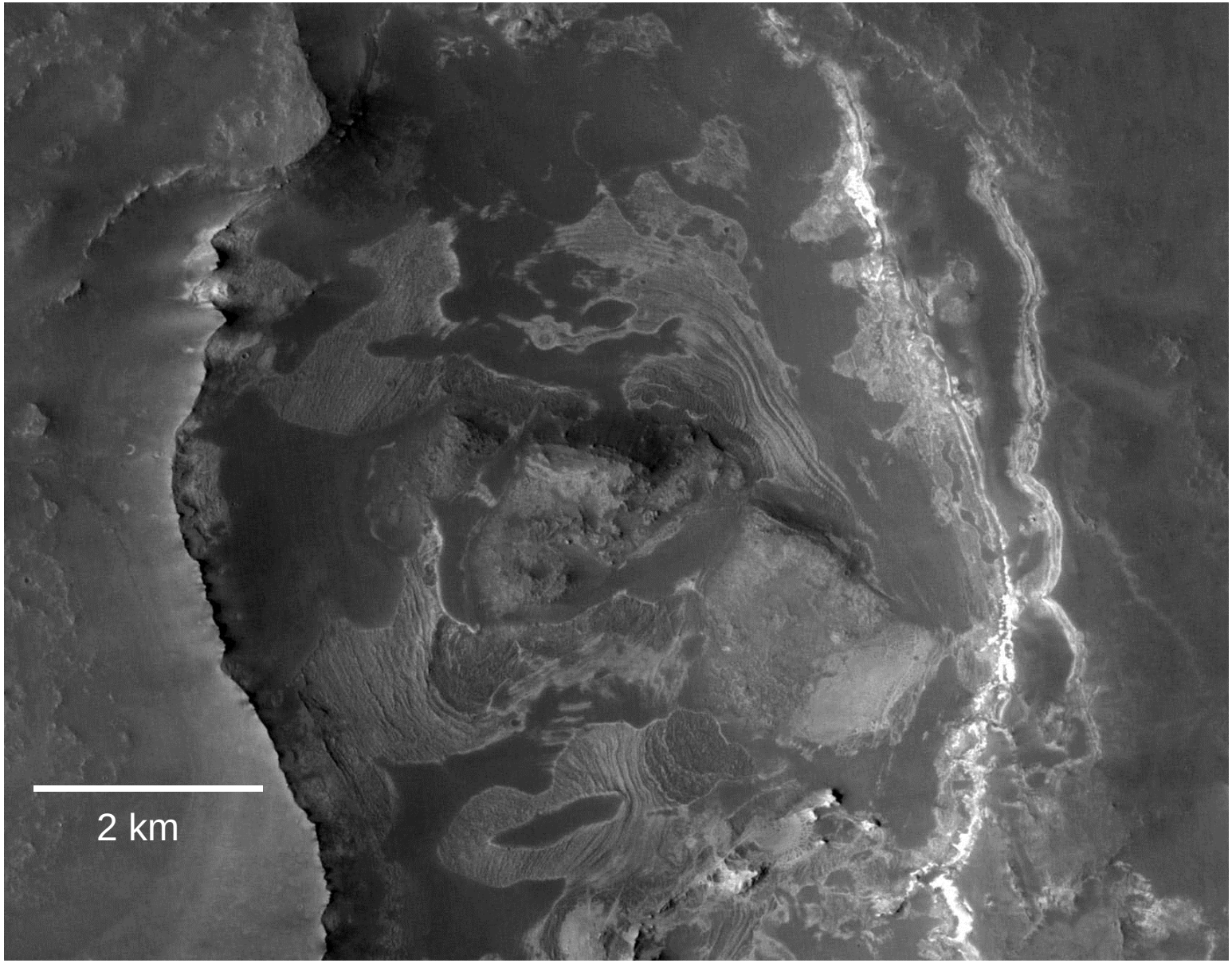


CTX+HiRISE over MOLA topography perspective view, 7x

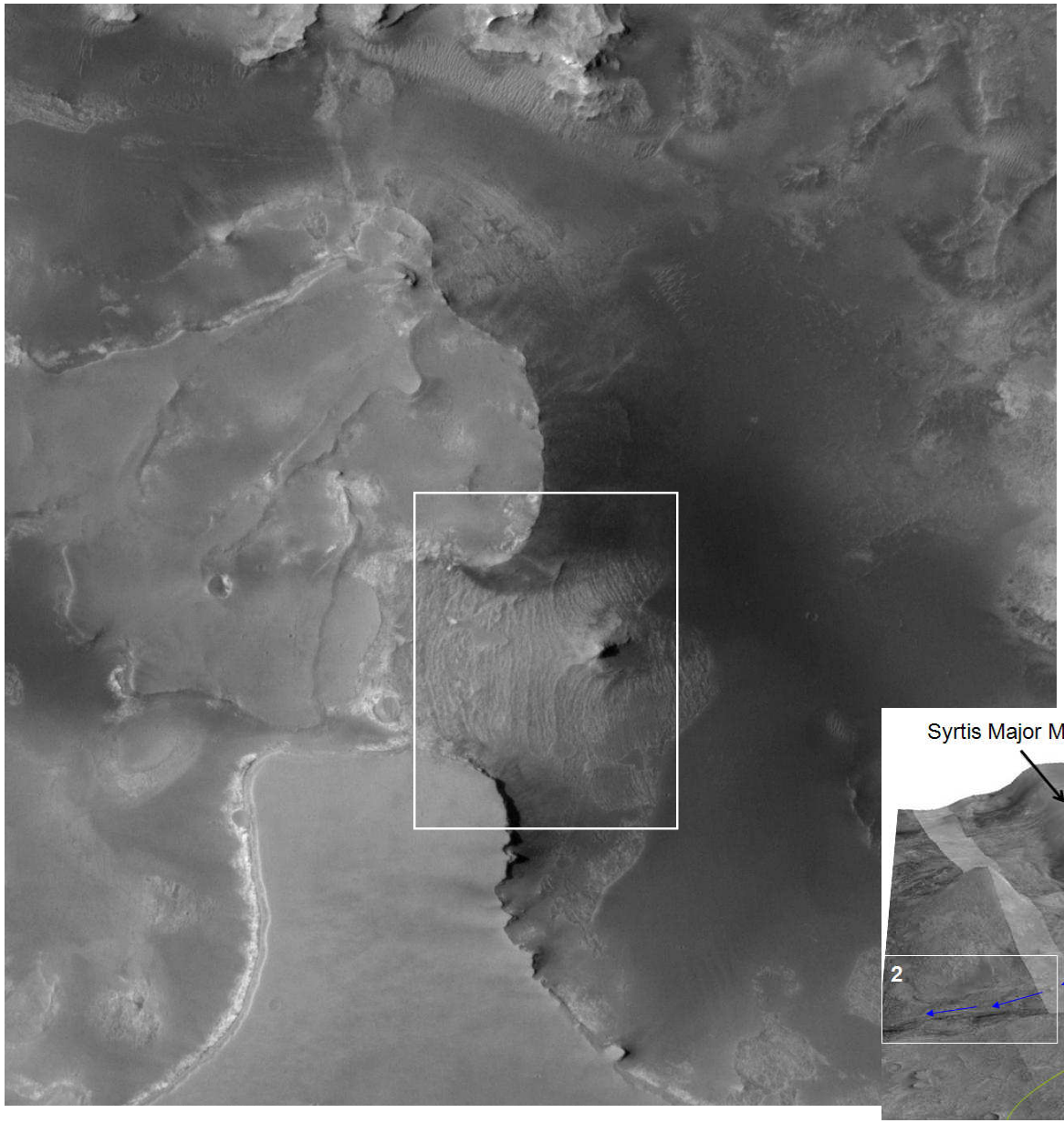
1. NE Syrtis inflow

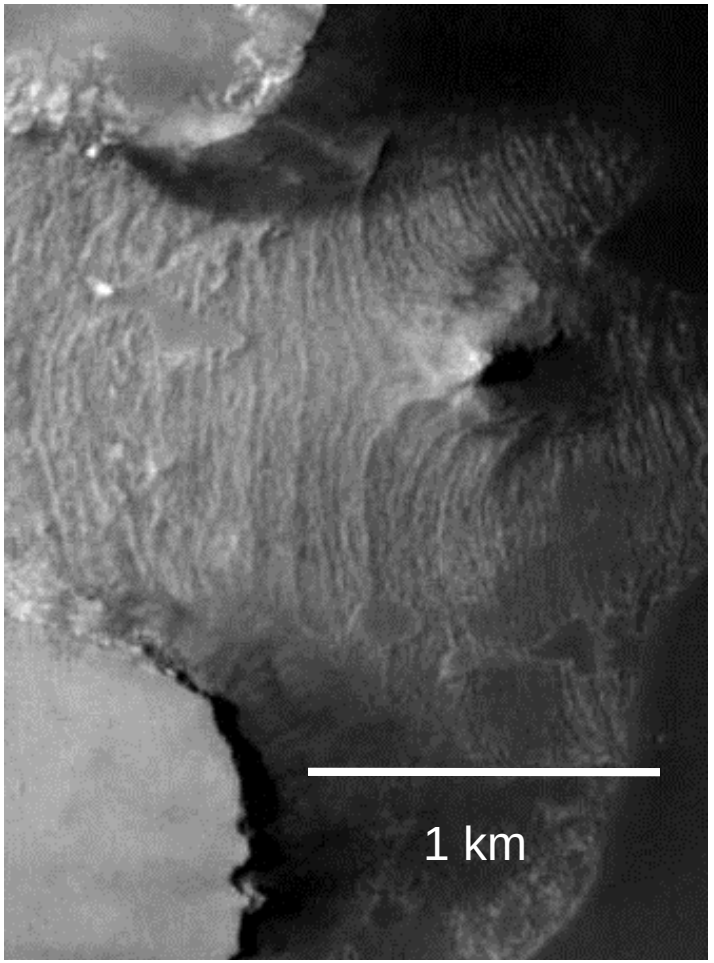


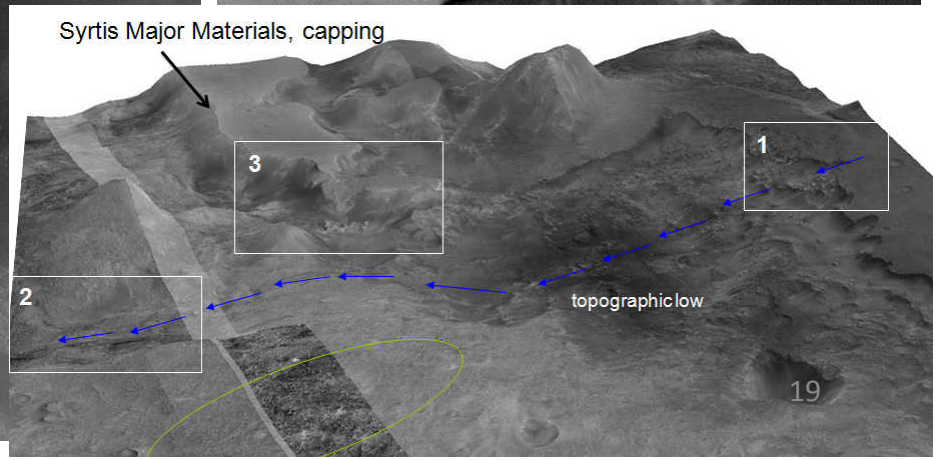
Beneath the capping lava is a 500 m stack of layered rock that appears sedimentary

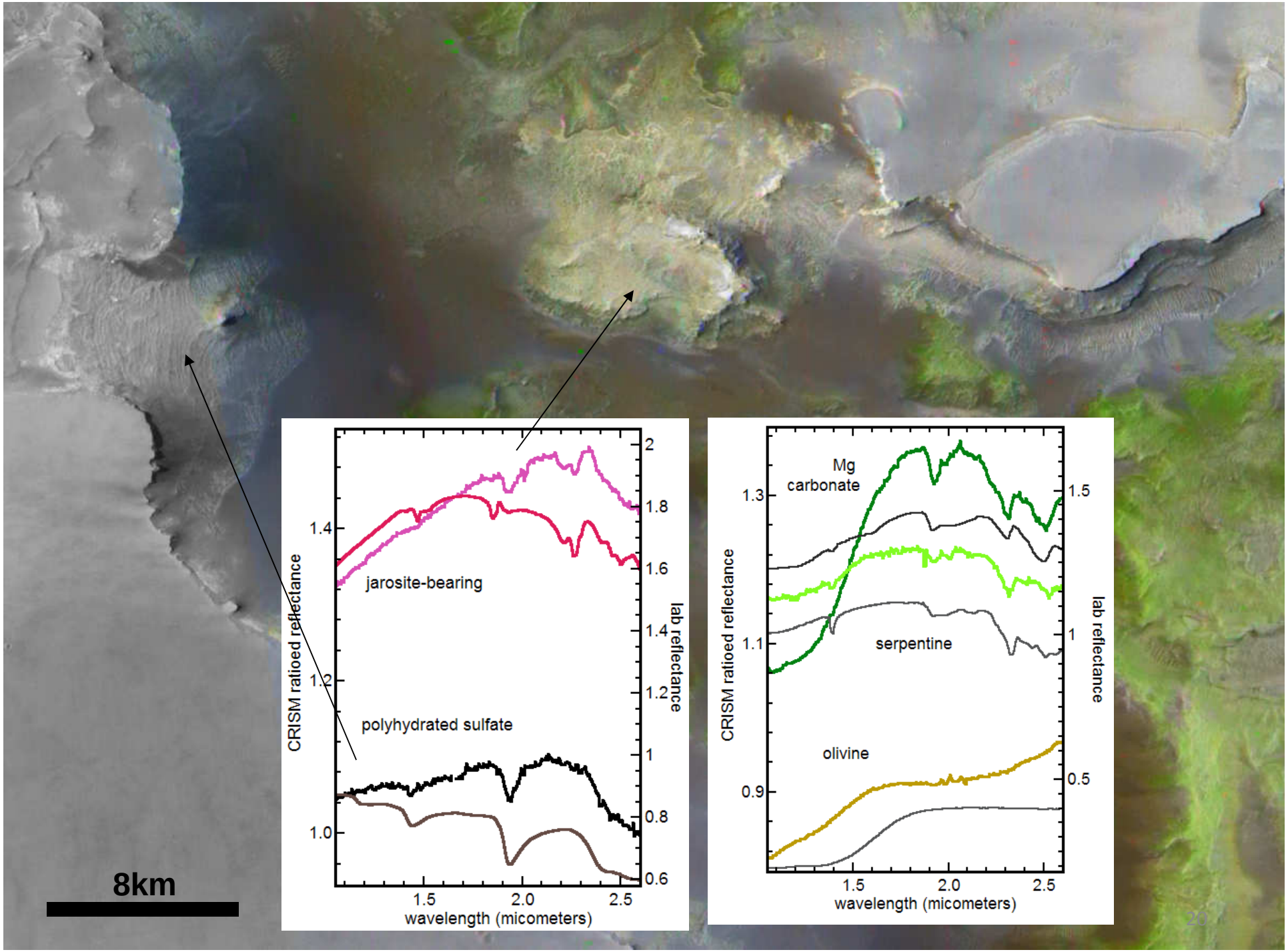


3. Beneath the capping lava is a 500 m stack of layered rock: Sedimentary?

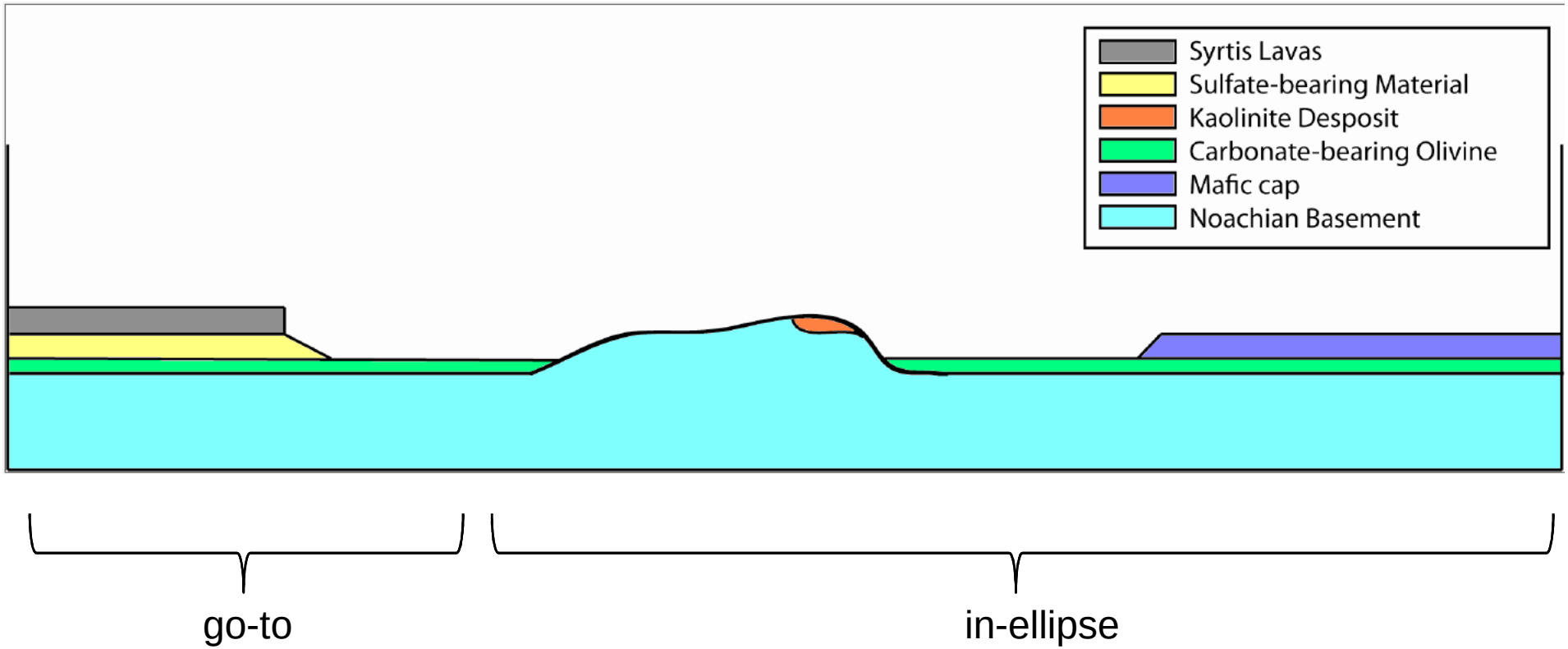




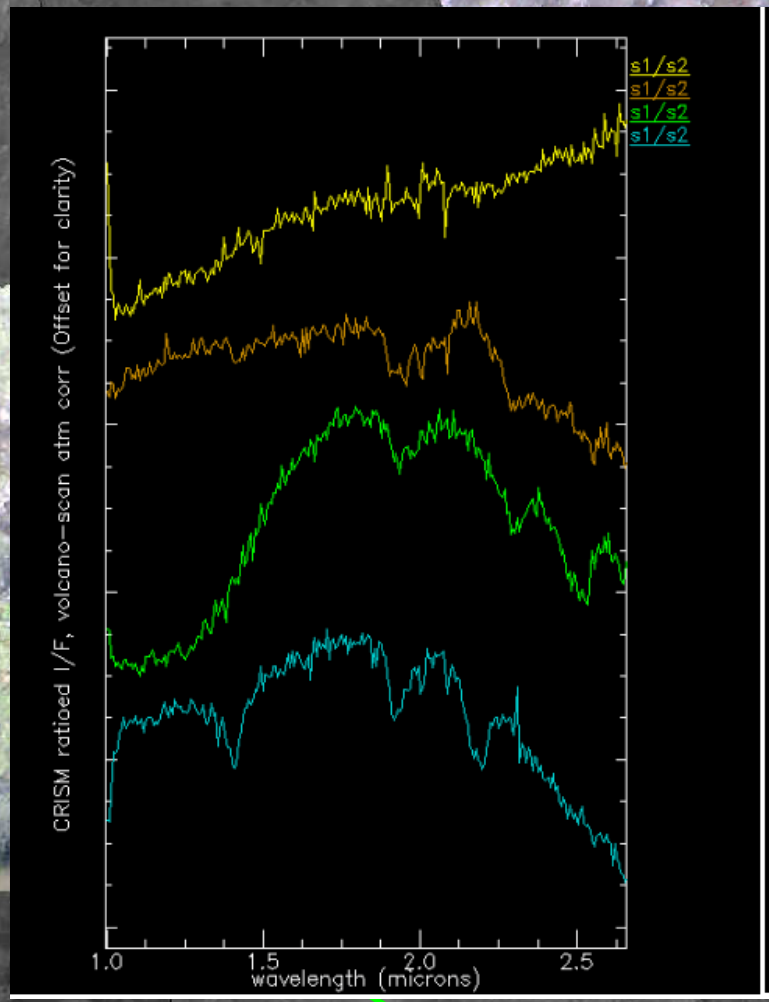


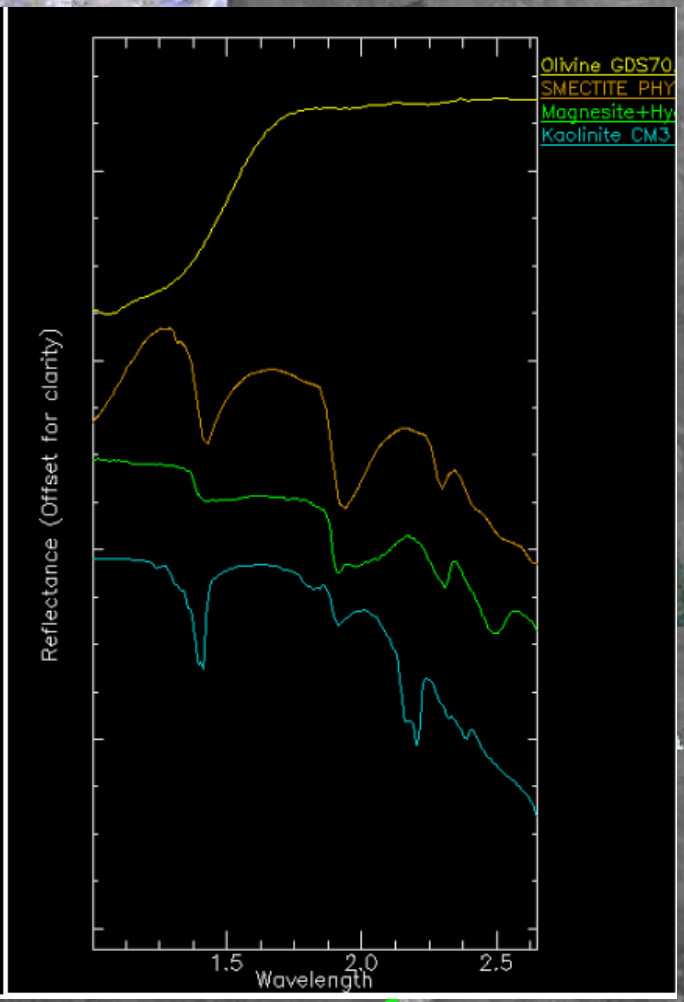

8km
jarosite-bearing
polyhydrated sulfate
CRISM ratioed reflectance
lab reflectance
wavelength (micometers)
Mg carbonate
serpentine
olivine
CRISM ratioed reflectance
lab reflectance
wavelength (micometers)

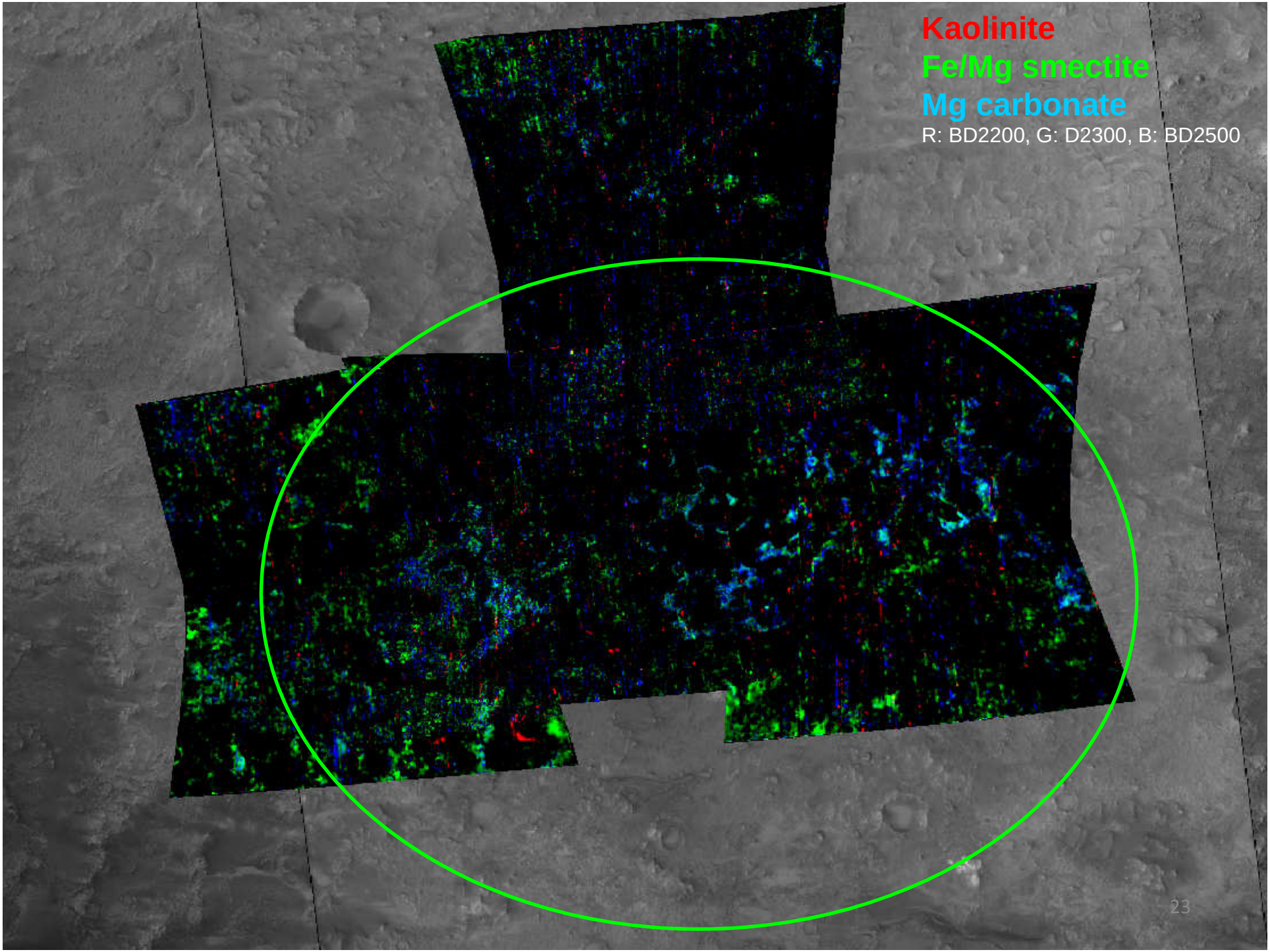
Regional Stratigraphy provides the context for in-ellipse and go-to science



In Ellipse Science and Notional Traverses






Kaolinite
Fe/Mg smectite
Mg carbonate
R: BD2200, G: D2300, B: BD2500

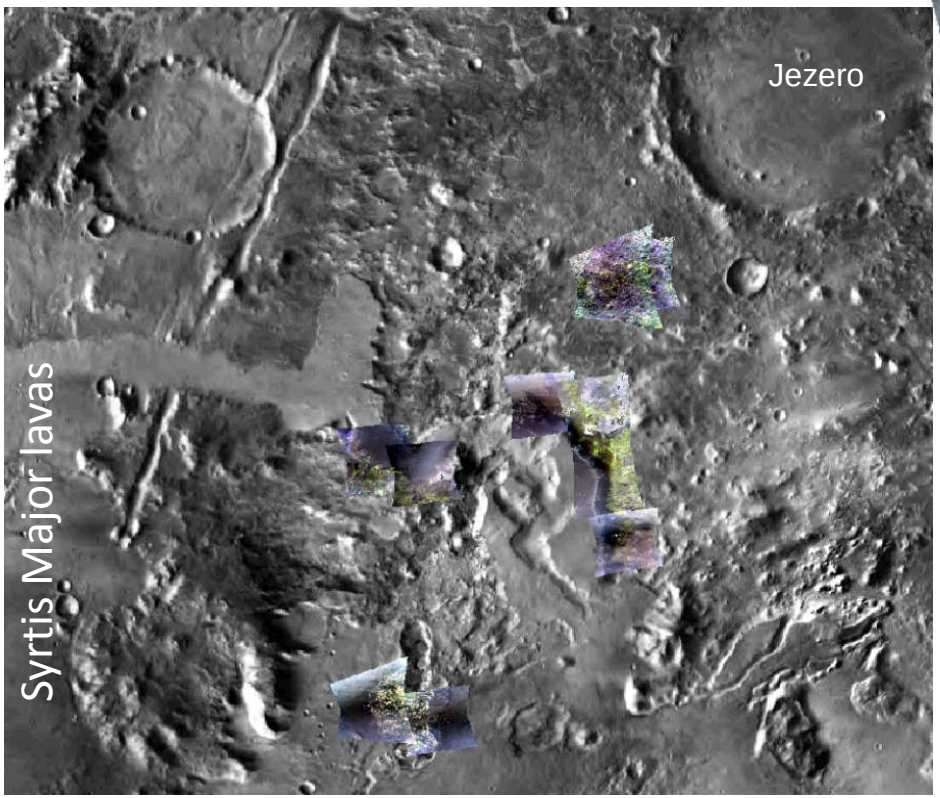
NE Syrtis Acid-Alkaline Transition

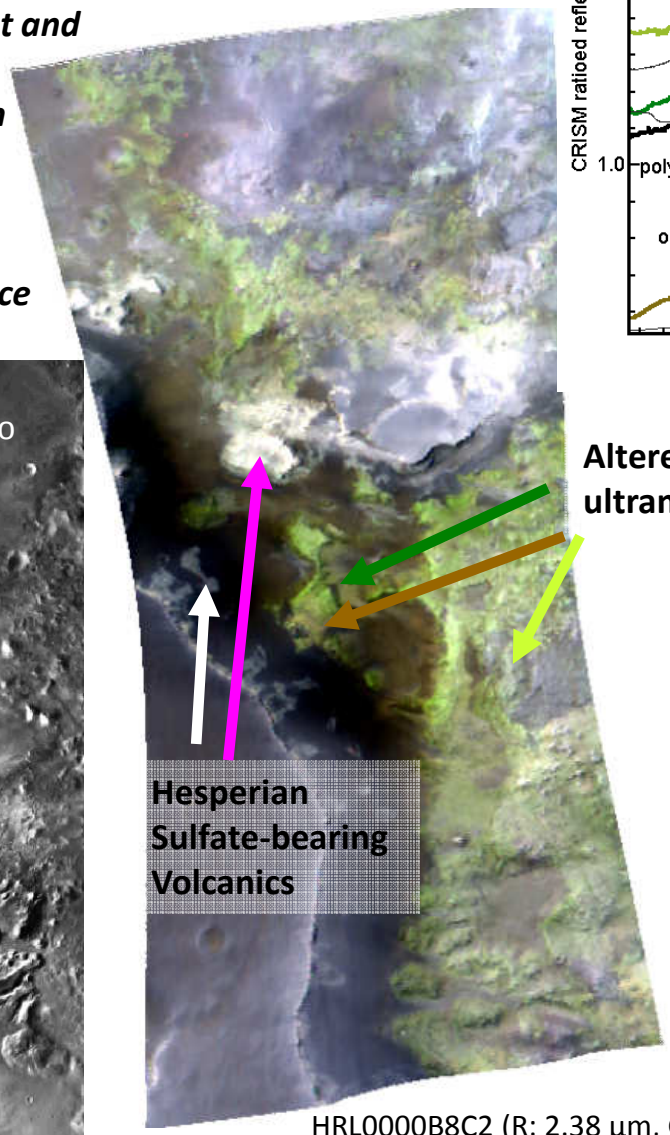
Cross the Noachian-Hesperian boundary and the transition from phyllosilicate/carbonate (alkaline) to sulfate (acidic)

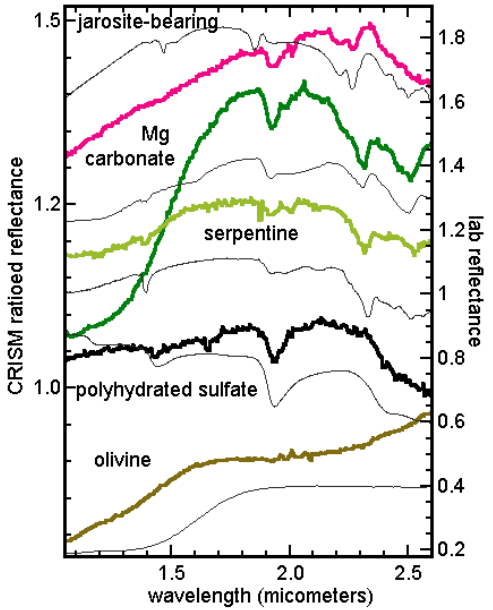
Emplacement of lava into a volatile-rich environment and onto the olivine-bearing units and Fe/Mg phyllo-silicate-bearing basement with serpentine formation

Sulfate deposits include jarosite and polyhydrated sulfate, largely with volcanic units

Evidence for circulation of fluids by heat of lava source







Altered Noachian ultramafic unit

In direct stratigraphic section and in situ are units that encompass many elements of the transition from the early phllosilicate-forming era to the later sulphate-forming era

Long record of aqueous processes with alteratior minerals

HRL0000B8C2 (R: 2.38 µm, G: 1.80 µm, B: 1.15 µm)

Conclusions

- Target-rich in ellipse science; go-to science traverses Noachian to Hesperian
- Bedrock strata in-situ representing four distinct environments of aqueous alteration where reactants and products are together
  - early crustal: creation or distribution by impact
  - carbonate/serpentine: surface alteration or hydrothermal?
  - layered phyllosilicates (Al- over Fe/Mg): from leaching with surface hydrology?
  - (sedimentary?) acid sulfate formation
- A record of aqueous geochemistry preserved in-situ, in mineral-bearing strata, distinct in age, primary mineralogy, and geologic setting well-suited for the MSL instrument suite
- Key stratigraphies from Bibring's Phyllosian and Theiikian eras: do the changes recorded here represent Mars global environmental change?